VTT Technical Research Centre of Finland

Aggregator Business Pilot

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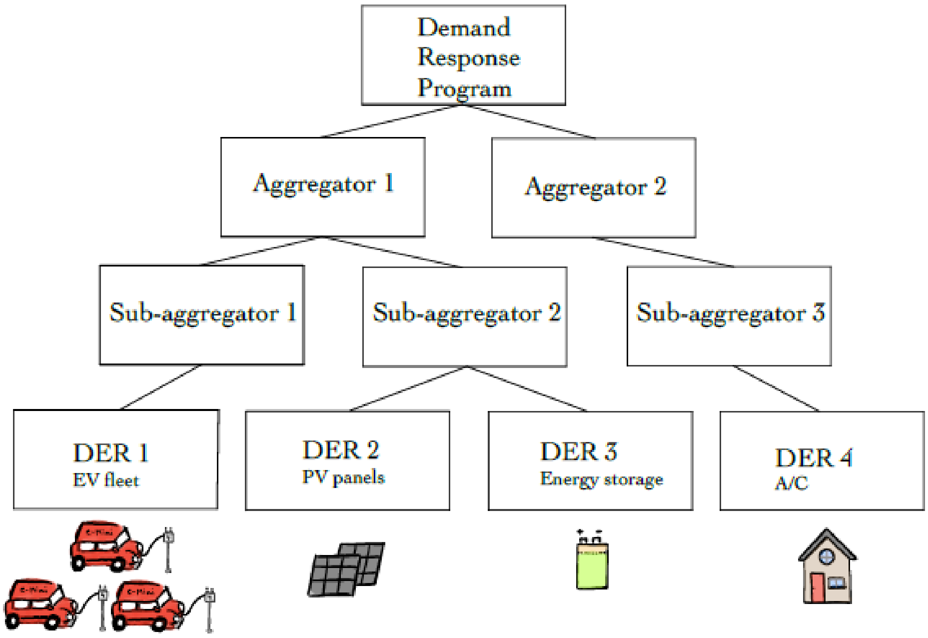

Aggregator Business Pilot

Authors: Matti Aro, Kari Mäki, Corentin Evens, Harri Vesa, Carina Schöpper

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Summary

This report is part of the results of Smart Otaniemi WP5, Aggregator Business Pilot.

This report presents the state of the art in aggregation and demand response schemes for providing flexivibility on different markets. The focus is especially on buildings and EV charging as example cases. More generally, concept of sub-aggregator is introduced and described. Sub-aggregator concept can be applied on multiple flexibility resources. The development of sub-aggregator concept includes technical interfaces, business model development as well as market studies. The findings are reported here.

Objectives of this work included business case development, specification of interfaces between the actors, implementing these interfaces and piloting them in real life. The progress of activities followed this structure. The actual pilots were built in the last period of this project, thus the follow-up on pilot results and experiences will take place in following projects.

As a part of this project, also international activities within Mission Innovation network took place. Summary of these activities is presented here, whereas more detailed results will be made available as scientific publication as the work progresses within the network.

During this project, the concept of sub-aggregator has been presented widely in different occasions. Also many events have been arranged for this purpose. Dissemination activities are also summarized within this report.

Confidentiality	Public

Tampere 27.10.2020

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Preface

Smart Otaniemi is an innovation ecosystem for smart energy solutions. It is part of Business Finland's Smart Energy program, and aims at being an internationally recognised and impactful smart energy innovation platform. The ecosystem and the testbeds are built modularly through business-driven pilots: the target is to become a showroom and gateway for Finnish energy excellence. Smart Otaniemi integrates co-operation, digitalisation, energy and users and forms a platform where business and research can work in tight collaboration accelerating new technology, services, business models and systemic solutions.

Steering group of Smart Otaniemi Pilot Phase 1 was comprised of following professionals: Tuula Mäkinen, VTT Technical Research Centre of Finland Ltd., Matti Lehtonen, Aalto University Foundation sr., Antti Säynäjoki, Aalto-yliopistokiinteistöt Oy, Harri Vesa, E2M Voimakauppa Oy, Jan Segerstam, Empower IM Oy, Chairman of steering group, Davor Stjelja, Granlund Oy, Jyri Öörni, Merus Power Dynamics Oy, Jarno Halme, Nokia solutions and networks Oy, Heikki Suonsivu, Parkkisähkö Oy / Parking Energy Ltd and Jussi Puranen, Väre Energia Oy. Ismo Heimonen from VTT acted as the Project Manager and secretary of the steering group.

This report is part of Smart Otaniemi Pilot phase 1, the pilot for,Aggregator Business Pilot (Work package 5). WP5 seeked to develop new cost-effective means for harnessing distributed flexibility within different processes and to bring this flexibility to markets.

Tampere, 27.10.2020

Authors

Contents

Introduction

The aggregator business pilot seeked to demonstrate forking value chains of aggregator business in Otaniemi, ranging from market activities into individual resource level. The pilot covered all levels involved in real aggregator business cases and created a development basis for all involved layers, also applicable in future projects. Interoperability within the value chain has been tested in real circumstances, applying real interfaces and ranging from market actor to individual device development.

Role of different sub-aggregators has been highlighted within this pilot. Sub-aggregator is understood as an actor having access to control of multiple resources such as controllable loads or generation units in its portfolio but on the other hand no active role on energy market level. Instead, the sub-aggregator can offer the controllability in its command to aggregator who takes the actions on market level. Typically sub-aggregator already has the monitoring and control possibility to its resources based on other needs, for instance maintenance and remote management purposes. Thus the monitoring and control connection to the resource is not built for aggregator purposes only.

Sub-aggregators can be for instance EV charging operators, PV system providers, facility management companies, building automation system providers or other system or device providers. Multiple potential sub-aggregators within Otaniemi area have been raised during this pilot.

Focus of the pilot has been in interfacing the actor layers. Realistic protocols and interfaces have been used where possible. Aggregator pilot participants have also built the necessary interfaces within this work package. In addition to technical interfacing, business models and information exchange have been considered.

Project objectives

The key objective for this pilot has been enabling research actors and companies working together to develop new business, both in terms of technical implementation and business model creation.

The aim of this project is also to improve the overall framework for consumption flexibility in the electricity market in order to develop innovative business models for activating flexibility. In this way, new business models in the electricity market can help to support the green transition and intelligent utilisation of electricity grid capacity.

A further objective has been to concretely develop interfaces and demonstrate the solutions in real circumstances. Specific attention has been on following cases:

- EV charging aggregation. Piloting EV charging control as a part of aggregator business. This case covered both technical interfaces for individual chargers as well as control possibilities for wide-scale parking areas or parking houses with EV charging capabilities. This case has been conducted in co-operation with EV Charging work package and coordinated with activities of Finnish-German EVALIA project.
- Building automation interface. Piloting the aggregation of small HVAC loads through building automation system. This case has been conducted in co-operation with building level intelligence work package. Buildings used for this purpose include VTT offices and VTT smart grid laboratory.
- Direct interface for big loads. This case considered using big loads directly for aggregation as a part of Otaniemi aggregator pilot. In this case a specific interface to the loads has been built. The piloting has taken place in VTT office building utilizing a major cooling unit.

Background

In power systems, the stability of the system is dependent on the balance between the energy produced and consumed at any given time. For example, if the energy consumed is higher than the energy produced (the same applies with the opposite situation), the difference will be provided by the inertia of the rotating machines connected to the grid. In that case, the machines will slow down and the frequency of the electric currents in the system will go down. Traditionally, the system operators would have agreements with generating units encouraging them to react to frequency changes by adapting their output accordingly. This is where the aggregator's business comes in.

The concept of an aggregator is to group resources which could help by providing system stability services, but which would not do so individually: there are rules (such as a minimum amount of available power) or fees that prohibit their direct participation, some would not have the technical means to achieve the required flexibility and some would simply not be interested in putting time and effort in making it possible. The aggregator contacts resource owners, making it easy for them to participate to the system stability and aggregates them in order to present a single product (pool) to the power system operators.

Three background aspects need to be covered in order to have a better idea of why and how an aggregator business can bring value: the global drivers, such as changes in the means of electricity generation and the developments in communication and control technologies, and the possibilities offered by the electricity and reserves markets.

Global Drivers

Global warming and climate change have been observed, studied, debated for several decades. In an attempt to mitigate the scope of the change, 190 countries ratified the Paris Agreement in December 2015. The European Union decided to take a predominant role in the efforts to reduce emissions and in strengthening societies' ability to deal with the impacts of climate change, both locally and in the form of support to developing countries.

In the wake of the Paris Agreement (in 2016), the EU set up an energy policy framework with the following key targets for 2030[1]:

- At least 40% cuts in greenhouse gas emissions (from 1990 levels)
- At least 32% share for renewable energy
- At least 32.5% improvement in energy efficiency

[1] https://ec.europa.eu/clima/policies/strategies/2030_en

In 2018 and 2019, the EU completed an update of its energy policy framework and published a new policy rulebook called the *"Clean energy for all Europeans package"* [2], but often referred to as the *"Winter Package"*. The package includes 8 legislative acts which need to be transposed into national laws within 1 to 2 years. The 8 pieces of legislation are the following:

- Energy Performance of Buildings and Energy Efficiency: Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018.
- Promotion of the Use of Energy from Renewable Sources: Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018.
- Energy Efficiency: Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018.
- Governance of the Energy Union and Climate Action: Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018.
- Risk-Preparedness in the Electricity Sector: Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019.
- Establishing a European Union Agency for the Cooperation of Energy Regulators: Regulation (EU) 2019/942 of the European Parliament and of the Council of 5 June 2019.
- Common Rules for the Internal Market for Electricity: Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019.
- Internal market for electricity: Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019.

The Electricity Market Directive (EU) 2019/944, in its article 2, introduces the concepts of "Active Customer", of "Demand Response", of "Citizen Energy Community", but most importantly for this work, of:

- Art. 2 (18) Aggregation: a function performed by a natural or legal person who combines multiple customer loads or generated electricity for sale, purchase or auction in any electricity market.
- Art. 2 (19) Independent Aggregator: a market participant engaged in aggregation who is not affiliated to the customer's supplier.

In addition, Art.17 (1-2) states that aggregated demand response should be allowed to participate to energy and ancillary markets in a non-discriminatory manner alongside producers.

Going back to the objectives of the Paris agreement, in the context of the aggregator business, it is possible to examine their impact in terms of decarbonisation, decentralisation and digitalisation (Figure 1).

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[2] https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en

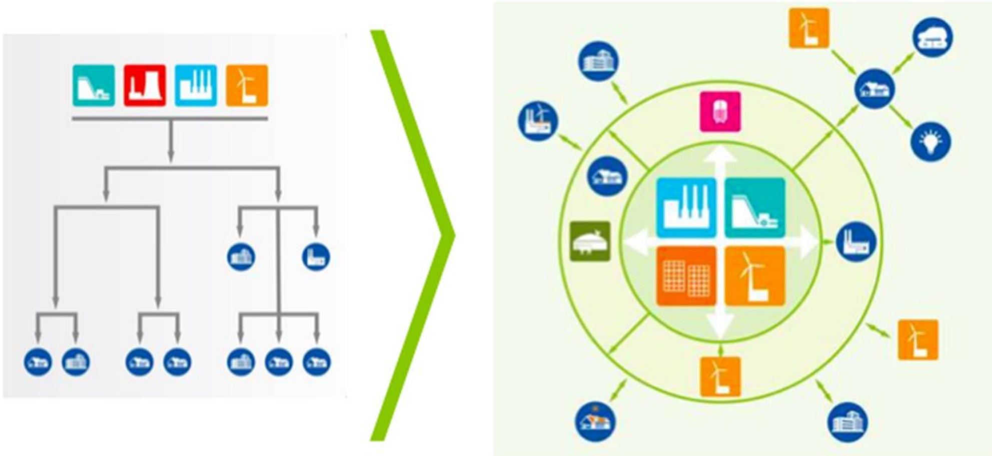


Figure 1. Decentralisation, Digitalisation and Decarbonisation are key elements in the ongoing Power System Transition

Decarbonisation

The most direct way for the energy industry to reduce greenhouse gas (GHG) emissions is to go through a decarbonisation process, i.e. phase out the carbon-based electricity production on combustion. This means products like coal, oil, natural gas, etc.. The three most common ways to reduce the GHG emissions are to reduce the emissions from the carbon-based plants or replace them with renewable or nuclear power.

The first one can be achieved by switching from carbon or oil-fired plants to gas fired ones, ideally with combined heat and power production capabilities, or by adapting coal plants with carbon capture technologies, or by increasing the efficiency of the plants. This solution is close to neutral in terms of system stability and available reserves, but it is showing its limits in terms of total GHG emission reduction.

As stated earlier, the replacement of thermal plants by renewable technologies substitutes the heavy rotating masses of the generator by power electronics. This creates a need for additional inertia in the system, although, with current technologies, wind or solar generating units are able to simulate the inertia behaviour of real machines [3]. Those plants are however unable, or at least not properly incentivised, to adjust their production in cases of frequency deviations. The same applies to nuclear power. Studies show that nuclear power is technically able to provide reserves services, but at a cost which would prevent them from participating in the current markets [4].

The consequence of this for an aggregator is that the at least volumes and possible also prices in the reserve markets would be likely to go up when the cheaply flexible thermal units are leaving the place.

[3] https://spectrum.ieee.org/energywise/energy/renewables/can-synthetic-inertia-stabilize-power-grids
[4] https://www-pub.iaea.org/MTCD/Publications/PDF/P1756_web.pdf

Decentralisation

Decentralisation is a consequence of the increased penetration of renewable production units. The governments in Europe have incentivised citizens or communities to invest in small renewable production units distributed all around the country. This signifies an important change from the previous situation with only some large thermal units located in specific places.

An impact of decentralisation is that the local systems (distribution networks) have not been designed with that possibility in mind. There are now localised problems appearing due to distributed generating units: over-voltage situations, line overloading or unwanted energy flows in the opposite direction. It becomes even more complicated when the interests of the local and of the global system diverge, such as too much local production for the distribution network, but a need for more overall production in the transmission network. An aggregator aware of the location of its assets and of their capabilities could offer services to the local system operator or participate to the coordination between the transmission and distribution system operators.

Digitalisation

The digitalisation of the world is a fact that is now difficult to ignore. It provides heaps of benefits, but can also come with some challenges. For an aggregator, it allows for fast and reliable communication as well as for smart control of the operated devices. The heart of an aggregator business is in its ability to collect and analyse data from its contracted devices and how to operate these devices remotely with sophisticated algorithms.

Another aspect is that the digitalisation of their operations can be an incentive for the resource owners to opt in to an aggregation business. An example of this is the installation of home control devices. Those devices integrate energy consumption controls which could be operated also to provide flexibility services through an aggregator.

Electricity Markets in Finland

Balance Responsibility

Fingrid as a TSO is responsible for maintaining the power balance in Finland. It monitors the grid frequency and activates power reserves in times when the frequency deviates enough from its nominal value. The adjustments are made by setting up and operating the ancillary service market. In order to recover the costs of operating those markets, the TSO requires that the participant to the markets are, to some extent, responsible for their own balance. They have to, in advance, balance their own production and consumption with their purchases and sales on the markets. Currently, the balance is measured and calculated on a 1-hour basis. Some market participants are directly responsible for their balance to the TSO: they are referred to as Balance Responsible Parties (BRP). Some others are responsible towards another actor (such as a BRP) which can pool the balance of several actors and reduce their costs by reducing the variance in their behaviour.

In May 2020, the Nordic TSOs have agreed that, starting on May 22nd, 2023, the balancing period will be shortened to periods of 15 minutes[5] (from the hour used previously). The impact of this change will be that the value of resources that can react fast and reliably will increase when this comes into force.

[5] https://nordicbalancingmodel.net/nordic-tsos-15-minutes-balancing-period-from-22-may-2023/

Fingrid’s Reserve Markets

Frequency Containment Reserves for Normal operation (FCR-N)

The provision of FCR-N services is a continuous adjustment of the production or consumption as a function of the frequency. The main technical characteristics are summarized in Table 1. The FCR services can be traded with Fingrid either on a yearly or an hourly market. For individual hours, the hourly markets have more attractive prices, but the yearly market provides the guarantee of being selected. Capacity exceeding the amount contracted on the yearly market can be bid on the hourly market.

The requirements for the participation to the FCR markets stipulate that participating storage devices should be able to provide power at full bid capacity for 30 minutes. It should be noted, however, that the assets that participate to those markets are not allowed to simultaneously be used for any other purposes.

The assets contracted to provide FCR-N services need to adjust their output continuously (with an admissible frequency dead band of ±0.01 Hz). In 2019, the prices for the capacity were of 13.5 €/MW on the yearly market and, on average, and 22 €/MW on the hourly market. In addition to this capacity fee, the energy provided is charged at the balancing price for that specific hour. The balancing price is market based, but always beneficial, compared to the spot price, for assets that help the system by providing frequency services.
Therefore, important points to consider about the participation to the FCR-N market:

- Units and their dedicated flexibility band width with accepted FCR bid are not allowed to provide any other services during that time.
- A storage unit dimensioned for a maximum service duration of 30 min will often become completely empty or full, thus unable to provide the service and have to pay the penalty fee (equal to the capacity fee)
- The provision of FCR services requires a measurement of frequency with the required accuracy and the ability to react fast enough.
- The provision of FCR-N has to be symmetric. Assets that participate are required to be able to provide the same volume and duration of their bid both as an upward and downward regulation.

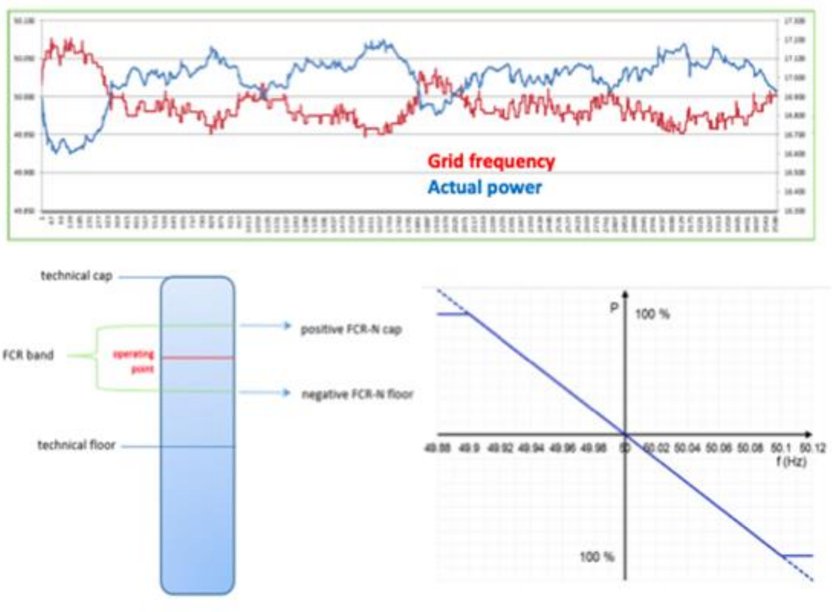


Figure 2. Operation logic of resources on FCR-n market

In order to avoid the penalties for failure to provide the service, it is possible to optimize the operation of a BESS by planning periods during which the SOC is brought back around 50% by paying the balancing fees or by combining it with other resources and be able to provide FCR-N services more often (as studies in D6.5 of the EU-SysFlex project[6]). The expectation however is that Fingrid is still in the process of refining the rules for the participation of reserves with a limited capacity to the FCR markets. Also pan-Scandinavian and European harmonisation is expected to take place. Therefore, the mentioned challenges will be alleviated once new regulations are in place. This could lead to the optimization mentioned above would become useless or against the contract rules.

Table 1 - FCR requirements[7] [8]

Product	FCR-N	FCR-D
Direction	Symmetric	Upregulation
Min size	0.1 MW	1 MW
Dimensioning requirement	30 min	30 min
Trigger	f < 49.99 Hz or f > 50.01 Hz	f < 49.9 Hz
Full activation criteria	f < 49.9 Hz or f > 50.1 Hz	f < 49.5 Hz
Time to 50% activation	n.a.	5 s
Time to full activation	3 min	30 s
Measurements (accuracy)	f (10 mHz)	f (10 mHz)

Frequency Containment Reserves for Disturbances (FCR-D)

FCR-D services are used in cases of larger disturbances in the system. A larger disturbance means the loss of a larger generating unit or the tripping of an important infeed line. For this reason, the FCR-D product is defined only as upward regulation, i.e. an increase of production or a decrease of consumption. Fingrid – Finnish TSO – has published their intention to develop also linear FCR-D downward regulation within the next two years. The product definition and the service procurement are very similar to those for FCR-N. FCR-D is also traded on a yearly and on a day-ahead hourly basis. A comparison between the main requirements of the two FCR services can found in Table 1.

There is a difference the way FCR-D resources with a specific storage capacity, such as batteries, should be operated. The technical requirements stipulate that the recharging of the capacity should be complete “as soon as possible”, but at the maximum 2 hours after the recharging has started. The recharging time is defined as the time when the system frequency is 49.9 Hz or above.

In 2019, the prices for the capacity were 2.4 €/MW on the yearly market and, on average, and 5.3 €/MW on the hourly market. In addition to this capacity fee, the energy provided is charged at the balancing price for that specific hour. The prices are much lower (4 to 5 times) than those for FCR-N, but the activation of FCR-D resources is a lot rarer than that of FCR-N.

[6] https://eu-sysflex.com/documents/
[7] https://www.fingrid.fi/en/electricity-market/reserves_and_balancing/frequency-containment-reserves/#technical-requirements

[8] https://www.fingrid.fi/globalassets/dokumentit/en/electricity-market/reserves/appendix3---technical-requirements-and-prequalification-process-of-fcr.pdf

The important aspects that should be kept in mind regarding the provision of FCR-D services are:

- Units with an accepted FCR bid are not allowed to provide any other services during that time.
- Running out of capacity after a 30-minute disturbance is less of a problem. The cause of the disturbance should be fixed or other reserves (Frequency Restoration Reserves) should have taken over before the 30-minute threshold.
- The provision of FCR services requires a measurement of frequency with the required accuracy and the ability to react fast enough.
- The provision of FCR-D is only in the direction of a reduction in consumption or discharge of a storage unit.

Fast Frequency Reserves (FFR)

FFR is the latest addition to the Finnish frequency reserves family. It was announced officially in December 2019 and is expected to be fully implemented by the summer 2020. Its introduction is the result of a decrease of the total inertia of the generation units over the system. Inertia is a measure of how fast the frequency changes in response to an imbalance in the system. With a lower inertia and in case of a large disturbance, the frequency varies too fast to ensure system stability by using the existing FCR-N and FCR-D capacities. By the time FCR resources are fully activated, the frequency would drop below the limits that the system can tolerate. FFR reserves are expected to react faster than FCR resources, but only for very short durations, until the activation of the FCR resources can stabilize the system frequency. The main characteristics of the FFR product are listed in

Table 2.

Assets able to provide both FFR and FCR-D services can submit combined bids, in which case, the capacity will be transferred from the FFR market to the FCR-D market if it was not selected during the FFR market clearing.

The important aspects that should be kept in mind regarding the provision of FFR services are:

- Units with an accepted FFR bid are not allowed to provide any other services during that time.
- Running out of capacity after a 30-minute disturbance is less of a problem. The cause of the disturbance should be fixed or other reserves (Frequency Restoration Reserves) should have taken over before the 30-minute threshold.
- The provision of FFR services requires a measurement of frequency with the required accuracy and the ability to react fast enough.
- The provision of FFR is only in the direction of a reduction in consumption or discharge of a storage unit.

Table 2 - FFR requirements[9] [10]

Product	FFR
Direction	Upregulation
Min size	1 MW
Dimensioning requirement	30 s
Trigger	f < 49.7, 49.6 or 49.5 Hz
Full activation criteria	n.a.
Time to 50% activation	n.a.
Time to full activation	1.3, 1 or 0.7 s
Measurements (accuracy)	f (10 mHz)

Automatic Frequency Restoration Reserve (aFRR)

The role of aFRR reserves is to bring the frequency back to its nominal value of 50 Hz. This brings the system back to its normal operation and relieves the resources used for the provision of FCR reserves. Fingrid procures aFRR only during specific hours in the morning and evening.

The definition of the aFRR product does not account for units with a limited capacity in the way that the products discussed before did. As a result, the provision of this service is less well suited to the participation of batteries. Excess demand response resources could however be used to provide aFRR.

[9] https://www.fingrid.fi/en/electricity-market/reserves_and_balancing/fast-frequency-reserve/#technical-requirements

[10] https://www.fingrid.fi/globalassets/dokumentit/en/electricity-market/reserves/the-technical-requirements-and-the-prequalification-process-of-fast-frequency-reserve-ffr.pdf

Table 3 shows the main characteristics of the aFRR products.

Balancing markets

The balancing market can also be referred to as the manual Frequency Restoration Reserves (mFRR). Although its purpose is the same as the one for the aFRR, it is better seen as a tool for Fingrid to, as the name indicates, balance the production and consumption by giving the opportunity to asset operators to provide bids up to 45 minutes before the delivery time.

There is no specific clearing time for the mFRR market. Fingrid contacts the bidders in price order until the balance is estimated to be reached. The price of the last activated bid is called to up- or down-regulation price and is used as a basis for the price of the imbalances incurred by all the balance responsible parties.

Table 3 - aFRR and mFRR requirements[11] [12][13]

Product	aFFR	mFRR
Direction	Up- or downregulation	Up- or downregulation
Bid size	5 MW	5 MW
Dimensioning requirement	Full bidding period	1 hour
Trigger	Activation signal	Phone call
Full activation criteria	n.a.	n.a.
Time to activation start	30 s	n.a.
Time to full activation	5 min	15 min

Research

Demand Side Management (DSM) has been recognized as very important aspect of tomorrow's power system management. Traditionally the balance between consumption and production has been managed by controlling the power production output but the replacing of controllable power generation units with intermittent renewables has flipped the operation logic upside down. Increasing amount of power production is either base load typed like nuclear power or weather dependent like solar and wind power. This has led to a situation where power systems around the world are forced to renew their operation logics. In practice this means wider use of demand side flexibility or Demand Response (DR), which is part of the wider term Demand Side Management.

It is important to acknowledge the fact that flexibility from demand side is not as straightforward as is the traditional production side management where controlling the output power was relatively easy with typically large intermediate storages and flexible power plant processes. Demand of electricity comes from the customized habits of individual humans and fine-tuned industrial processes which are used to receive electricity always on demand. It requires a significant change in the mindset of humans to rethink the behaviour and industrial process patterns to support the green power production of tomorrow.

The change in power production is believed to result in overall decrease in electricity retail prices but much higher price volatility. This means that those capable of choosing the time that they consume electricity will pay generally lower prices than those that have no flexibility. Choosing the time of consumption requires planning and a level of flexibility. In the future, it will be essential to know when and how much electricity use can be rescheduled for times of lower electricity prices and what risks there are to do so.

The challenge in the renewable energy dominated power system is how to optimize the use of intermittent power production with the existing grid that is designed for centralized power production. An increasing amount of power production is distributed at remote locations in the power grid and the reverse power flows require better monitoring of the grid to ensure its safe use also in the future. Weather forecasts will play ever increasing role in the power system management where consumption has to cope with the intermittent power production.

In the future, forecasting the demand will continue having a major role but unlike in the past where that information was used to plan the generation, it will be used to estimate the need for

[11] https://www.fingrid.fi/en/electricity-market/reserves_and_balancing/automatic-frequency-restoration-reserve/

[12] https://www.fingrid.fi/globalassets/dokumentit/en/electricity-market/reserves/automaattisen-taajuudenhallintareservin-afrr-teknisten-vaatimusten-todentaminen-ja-hyvaksyttamispr_en.pdf

[13] https://www.fingrid.fi/globalassets/dokumentit/en/electricity-market/reserves/reservitoimittajien-mfrr-ehdot-ja-edellytykset_en.pdf

flexibility to match consumption and production. Real time monitoring of the power system will also be more important in the future as will be the real time controlling of flexible electricity assets. The change towards renewable generation dominated power system has already started and the pace of the change is expected to increase in the following years. It will be essential for Finland to harness the under veiling flexibility in a sustainable and cost-effective manner to promote green transition while maintaining efficiency in the grid.

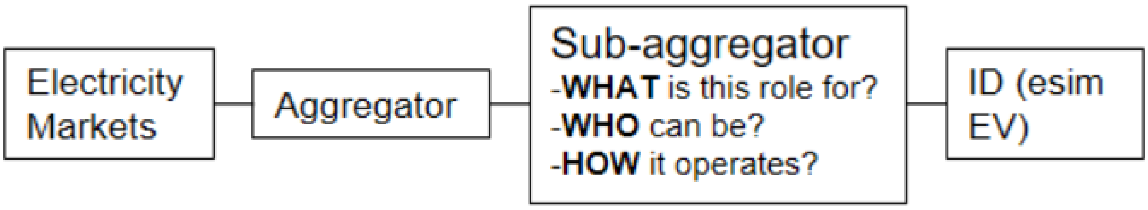


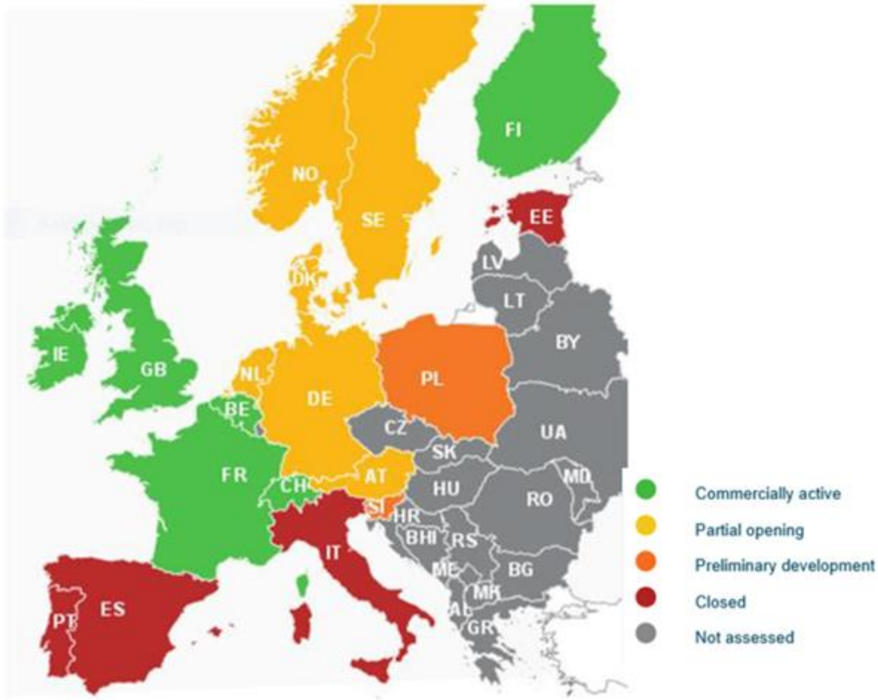
Figure 3. Research in this project focuses on Flexibility Value Chain. Moreover, it answers the what-who-how questions about Sub-aggregator role.

Flexibility in the power grid

In future it is likely that the distribution grid companies will also call for flexibility in order to meet the challenge of ensuring sufficient capacity in the distribution grid. Their demand for flexibility will increase with the growing infeed of renewable energy generation and the general electrification of our energy consumption. For example, increasing number of electric vehicles will lead to situations where peak demand might exceed the local distribution network capacity. This calls actions from also consumers so that new grid enhancements can be avoided and hence total cost be decreased benefitting all parties.

In Finland, large industrial players are already providing DR services for the TSO, but the increasing need for flexibility requires smaller players to participate too. Aggregators have the key role in bringing more flexibility to the markets. They are specialized in combining the flexible potential of smaller players into bigger entities. For small or even medium (under 100kW of flexibility) players it is necessary to combine forces with others since the current flexibility markets, such as Fingrid's reserve markets, require a minimum bid size of 100kW.

Household consumers can also participate in the electricity markets via (sub-) aggregators with some of their electrical equipment such as hot water boilers, air conditioning units or electric vehicles. However, the flexible potential is relatively small to really make the business case for it, especially when considering the initial investment that usually needs to be made in the monitoring and controlling capabilities. In addition, people tend to value ease of life and comfortable living conditions which again limits the flexible potential.



Source: SmartEN

Figure 4. Uptake of demand response varies significantly across the EU member states

Value of flexibility

Flexibility in the power system will have an increasing role and value in the following decades. More and more power production will come in the form of renewable energy such as solar and wind power. This will require active measures from demand side so that the intermittent power production is used effectively when it is produced, ideally so that no energy storages are needed. In reality some forms of energy storages will be needed, since the modern society and the industrial processes have evolved to require electricity on demand. Also the electrification of mobility as well as many industrial processes will impose greater requirements for the proper function of electric grids.

However, even though energy storage prices are constantly decreasing, it is not expected that they could compete cost effectively with flexibility from demand response in most cases. There have been no recent studies in Finland to assess the flexible potential that could be easily harnessed, but the estimates that were made by VTT already in 2005 hint that there should still be even as much as 1 GW of flexibility alone from the Finnish industry.

Geographically distributed household consumers also hold a significant flexible capacity when combined together. Individual consumers can provide flexibility by allowing a third-party aggregator to manage some of their biggest consumption units, such as water heating units, air conditioners and electric vehicles. Value from household flexibility comes when combined together with other similar loads, the impact of individual consumers is relatively small and thus not sufficient to make a difference for the power system nor even for the electricity bill of the consumer itself.

More generally, it could be said that currently smaller units than 50 kW are not profitable in DR schemes unless there is practically no need for hardware investments to enable DR. The possible savings or earnings from DR have to be larger than the investments made to enable it in a reasonable time scale. The “reasonable time scale” is up for anyone to decide, but from initial surveys from the Finnish industry it might be as short as one or two years which makes hardly any investment profitable. On top of hardware costs, personnel need to be educated about the changes that will happen in the functioning of the identified flexible resources. Some manual tasks might also be needed, even if it were just setting up the DR parameters again once in a while.

Also, for household and process industry resources some DR programs might cause disturbance on surroundings, for example, unscheduled programs such as frequency support could affect the living conditions that the user experiences. These aspects should also be considered when assessing the total value for all participants, especially the resource owner.

On top of flexible resources, demand response actions require hardware like monitoring and controlling equipment and data processing capacity. It also needs software so that the DR operations can be automated as much as possible including data and money flows between parties.

Value in demand response is created when harnessed flexible capacity is appointed to a specific DR program. In some cases compensation is paid already for the reservation of capacity but sometimes only after the flexibility is activated. The activation is made to serve a purpose that they are appointed to and. The value is determined by the existing market for that kind of flexibility.

Forecasting the future value of flexibility is challenging since it is a factor of multiple variables, such as the nature and amount of power production in the electricity markets and amount of supply in the flexibility markets. These are currenlty driving the value in opposite directions. On one hand, the share of wind power production is estimated to grow from 7% to 17% of the total consumption in few years (Figure 5), which will grow the need for flexibility and thus increase its value. On the other hand, demand response is available more and more as new players enter the market, in the summer 2020 the first large scale battery storage unit in Finland was anounced sizing 30 MW / 30 MWh. Some uncertainties also derive from the reshaping of electricity markets closer to real time. Balancing period will be reduced from 1 hour to 15 minutes and at the same time technical requirements for the activation of flexibility are tightened.

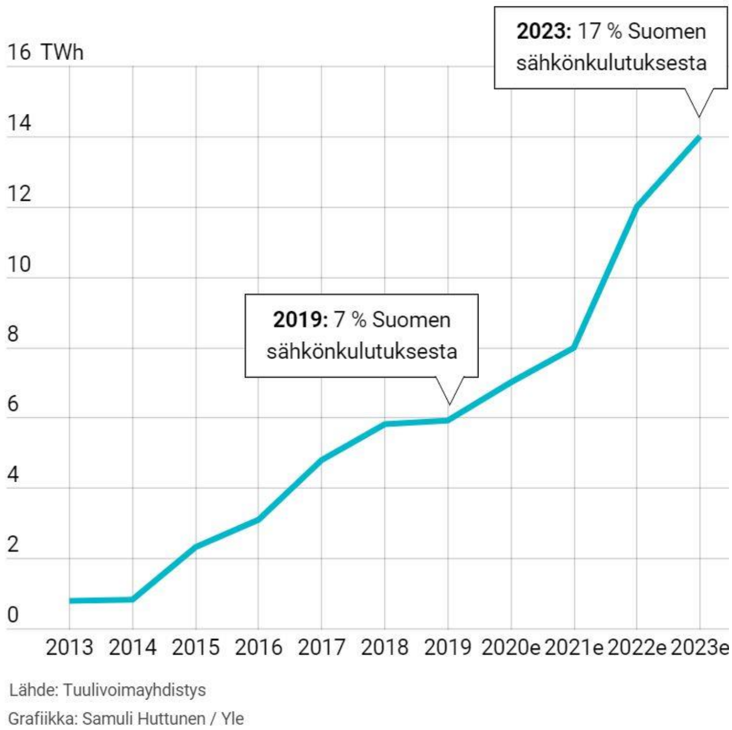


Figure 5. Expected growth in wind power production in Finland from 2020 to 2023.

In this project, we started from a presumption that large investments into automation systems would not be considered to enable Demand Response. Instead, existing capabilities should be more carefully considered and that should be our starting point in finding more flexible capacity. This was mutually agreed by the project partners and so the research work itself was going to focus in defining the DR value chain around the enabling link which is called sub-aggregator.

The Figure below presents the commercial players in this project mapped in the demand response value chain. As it can be seen, in this project we had one commercial aggregator and six sub-aggregators. VTT acted as a project coordinator whereas Fingrid represented the actual market place (reserve markets in Finland). In this project the research goal was to develop functioning, sustainable and equal business models for sub-aggregators to provide a gateway to flexible capacity that could be harnessed without major investments in monitoring or controlling capabilities.

Flexible resources

The basis of any demand response schemes are the controllable electrical devices that can be monitored and - on some level - forecasted. Flexible resources can be owned by individual end-users such as household consumers or corporations. These resources are sometimes referred to as Distributed Energy Resources (DER) since typically they are geographically separated from each other but still operated in a centralized manner when providing DR services. The next picture supports in selecting suitable units / devices for aggregated pools and flexibility markets.

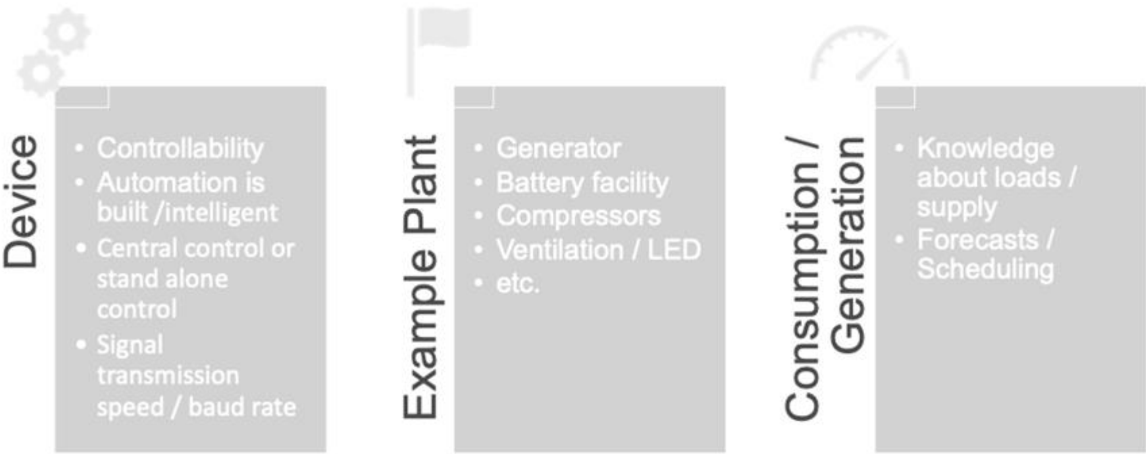


Figure 6. Technical Requirements for the Flexible Resource (Source: e2m material)

Flexible resources are naturally the key ingredient in DR schemes since they are the physical part of the power system that needs the flexibility. Flexible resources themselves can vary almost in all features. Only thing in common is that they either consume or produce energy and the power can be somehow controlled. Energy storages are sometimes separated from these two previously mentioned since they can be both consumption and production, but in terms of flexibility, it is perhaps not meaningful to distinguish it from the two since in flexibility markets only the power change in either direction counts and not the application itself. In Finland Energy Storages are in regulation considered to be in consumption pool side.

It is somewhat safe to say, that currently all energy devices in Finland are connected in the power system to serve a purpose other than that of providing flexibility for the system. In the future there will most probably be energy storages connected to the grid solely to provide grid services too, as early news from a 30MWh Battery Energy Storage System (BESS) by Neoen were republished in June 2020. But still the great majority of devices are there to serve humans not the grid. Their applications range from space heating and providing access to Internet to transporting people from one place to another, just to name a few. The point is, they are generally there to serve a somewhat acute need and rare are the occasions where flexibility is abundant with no drawbacks. Related press release is attached:

https://www.neoen.com/var/fichiers/20200609-neoen-media-release-ypr.pdf

Virtual Power Plants

At the core of aggregator operations is a Virtual Power Plant (VPP) which is basically a digital platform that connects Distributed Energy Resources (DER). Through the VPP an aggregator can not only monitor and control the DERs but can also apply schedules and logics and set triggers for certain events. The picture below presents the basic idea behind VPP.

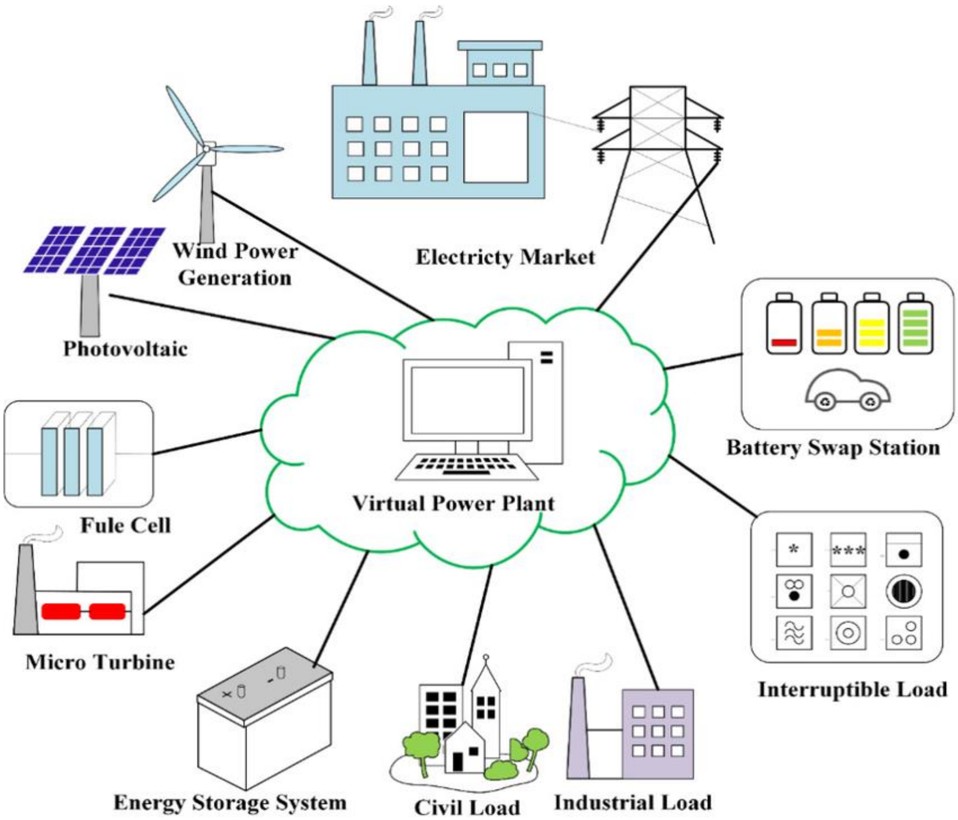


Figure 7. Virtual Power Plant connects Distributed Energy Resources together

Virtual Power Plants can be used to pool flexible energy resources that are geographically dispersed and different in technical capabilities. Pooled assets can then be used together on different flexibility markets. This allows aggregators to bid also with assets that might not be sufficient on the markets in terms of capacity or activation time. The resources that are pooled inside a VPP and bidded together on some flexibility market can also be owned by different people/companies.

Virtual Power Plants enable flexible resources to be used in a more efficient manner by combining available assets dynamically to ensure maximum yield always from the most beneficial market.

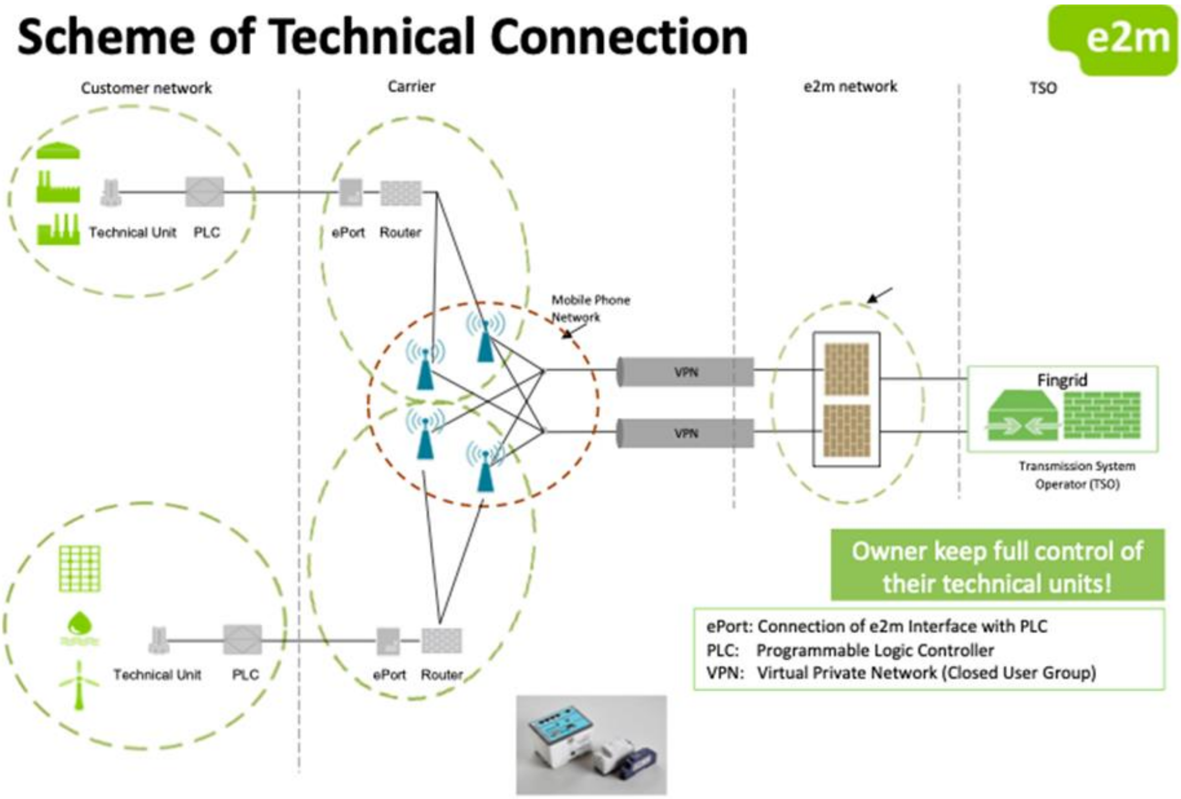


Figure 8. Information Topography of VPP used in this project (Source: e2m material)

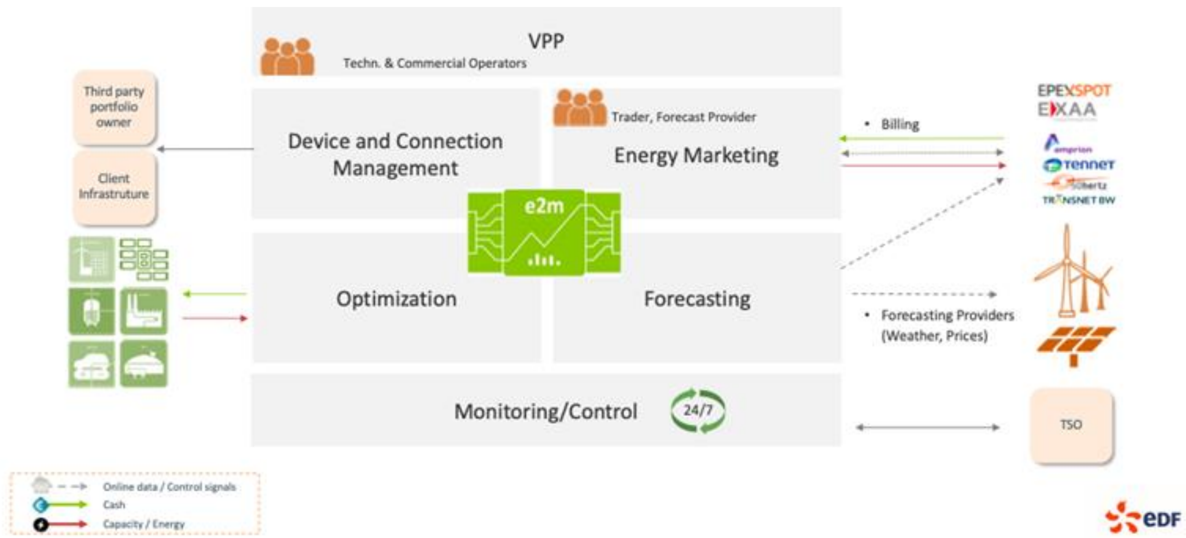


Figure 9. Cash and information flows in a functioning VPP (Source: e2m material)

Operation on multiple markets

During this project we also looked into the possible of aggregators to use their flexible resources more dynamically on different flexibility markets. For example in Germany it is already possible to make bids to some markets with undefined flexible resources. In this scheme the aggregator operates it's VPP so that the individual resources are not locked to any specific market. Aggregator is responsible for the proper functioning of the VPP and after the reserve activation signal it needs to be able to point the individuals that responded to the signal at each time. This allows aggregators to use their flexible resources more efficiently. Some resources can also be left as reserves so they can support the VPP if other resources fail to deliver.

Currently in Finland, the operation on multiple markets is not possible. In Finland, aggregators need to reserve all resources to a specific market in advance. This makes the use of flexibility inefficient compared to the more dynamic use of the resources since a lot of times the flexible capacity is not activated and just waits idle for the activation signal.

To give an example of the possibilities the dynamic use of flexible resources could offer, we can imagine a scenario where two identical resources are located in different parts of the grid. Both resources are preliminary reserved for FCR-d, but the amount of reserved capacity is only half of the total flexible capacity of the two resources. By doing this, the aggregator can always choose which one of the two resources it activates. The other can be left ready for another purpose, for example, a local load balancing or grid constraint management. The figure below presents different demand response products divided on groups based on the purpose they are designed for.

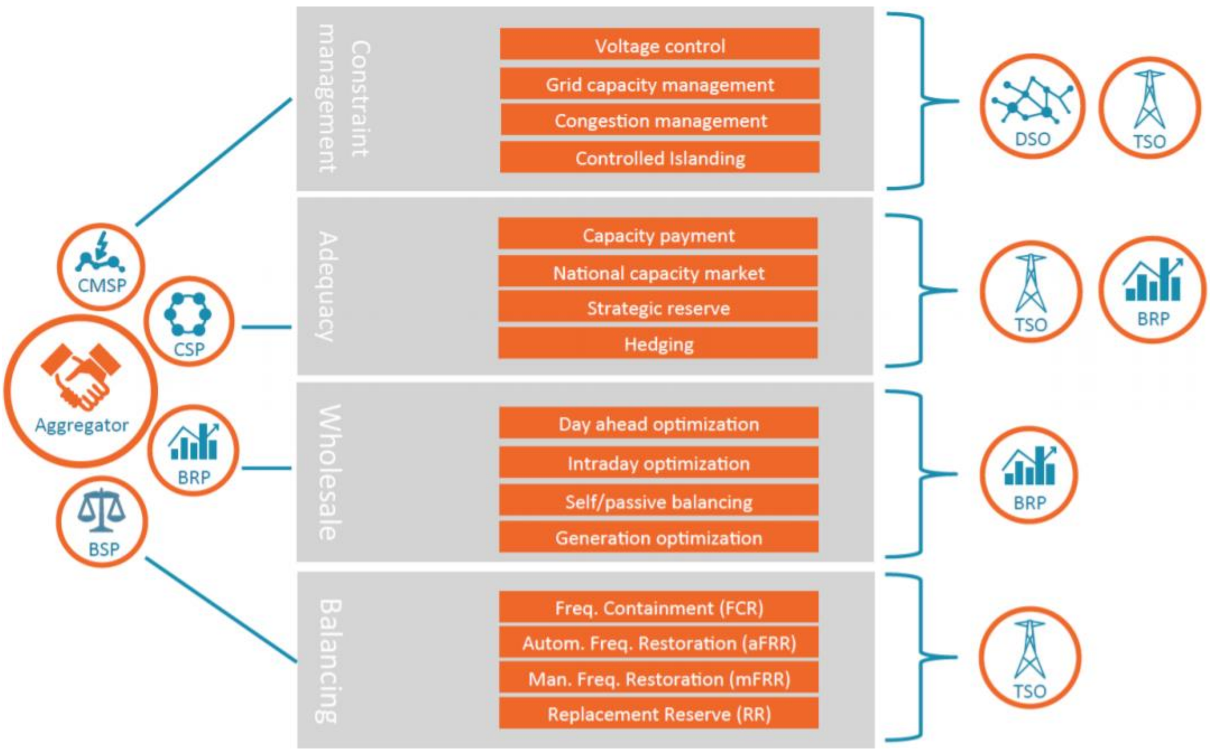


Figure 10. Organised markets and products accessible for flexible resources (Source: European Commission 2019)

Business Models

In the electrical grid, the balance between consumption and production must be equal at all times. This poses a challenge for the grid operators since a large portion of both consumption and production units have a stochastic nature. This means that the power they either take in or put out cannot be fully forecasted in advance. Traditionally the power generation has followed the demand by adapting the output power to real-time demand. With increasing amount of renewable power generation, this will no longer be economically viable. New sources of flexibility, mainly from consumption side, are needed for securing the power balance in the future.

Fingrid, as a TSO in Finland, is responsible for the power balance in collaboration with other Nordic TSOs. They govern national reserve markets where flexible power capacity can be offered by consumers and producers of electricity. The offered flexible capacity has value that is determined by the amount of supply (total flexible capacity in the markets) and demand (the need for flexibility).

In this project our main interest was in a demand response scheme containing four involved parties: DER owner, sub-aggregator, aggregator and marketplace. This approach was chosen based on former research on aggregators. The problem with traditional aggregation business had been that the integration of new flexible resources (units) into the VPP was often too expensive.Operating on electricity markets requires precise metering as well as reliable and fairly fast remote controlling capabilities and installing these would almost always be too expensive.

For that reason the research in this project was first focused on finding such existing actors that could already monitor and control large masses of consumption units, but are not exploiting the flexible potential hidden there. For lack of a better word, we call these actors as sub-aggregators, based on their position in the proposed value chain. These aub-aggregators include, but are not limited to, cooling- and heating pump manufacturers, smart charging service providers, forest-, chemical- and metal industries with their hundreds of individual processes with intermediate storages. These actors are, in a sense, natural aggregators. However, since their primary business is not on electricity markets but rather in a service field, their knowledge and thus initial interest is often not towards adopting new business models for flexibility. In this project, we hope to find business models that encourage potential sub-aggregators to participate in this act which would not only be beneficial for them but also for nature.

Demand response in principal is straightforward, there are grid or BRP needs for flexibility and then there are flexible resources that execute the supporting action. However, the use of electrical devices is mainly designed to fulfil end-user needs and not external needs. To switch the focus from end-user needs to external ones, some changes are needed in the behaviour of end-users and also in the technical functions of the resources themeselves. End-users are not willing to sacrifice their own time and resources for the sake of external needs unless the compensation is deemed sufficient. The current value of flexibility is generally not high enough to incentivise end-users to change their behaviour based on external signals and so the activation of flexibility is mainly outsourced for third party actors such as aggregators and sub-aggregators who take care of the flexible resources in a way that doesn’t require too much from the end-users. In a figure on the next page the basic value chain for demand response is presented.

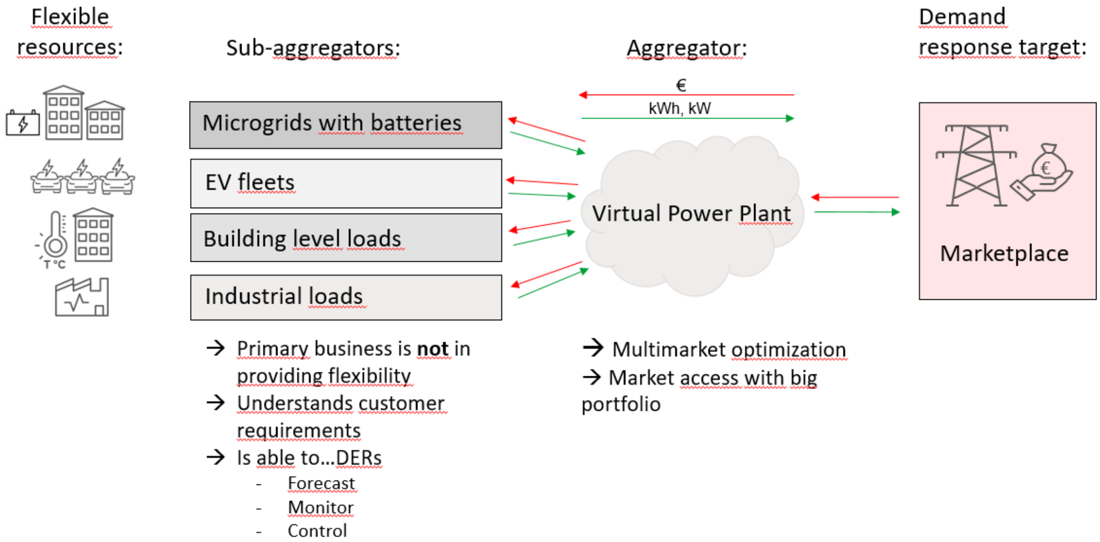


Figure 11. Demand Response Value Chain

Aggregators

Aggregators are the brain in the demand response value chain. Their function is to combine the available flexible capacity from the end-users into virtual power plants (VPP). The flexible capacity is then offered to different marketplaces of flexibility. The management of a VPP means constant optimisation and re-grouping of individual flexible resources so that the market needs are answered as efficiently as possible.

Aggregator can help to stabilise the electricity system and minimise the risk of power failures at times when the energy system is under pressure. For BRPs, aggregator can create value by decreasing imbalance or otherwise help in flexible portfolio management. The aggregator pools flexibility from customers and converts it into electricity market services, for example for use by the TSO, DSO and/or BRP.

The business goal for aggregators is to find ways to get large masses of flexibility to the markets with as low costs as possible. It had been recognized by our previous research that the most challenging part of harnessing more flexible power was the industry’s lack of interest to invest money in the needed technical capabilities. Due to the volatile nature of DR value and the uncertainty of the future valuation of it, companies as well as households have been doubtful to make investements in the DR capabilities where the payback time could span for several years ahead. Next chapter about sub-aggregators answers how we have been tackling the challenge of harnessing new flexible capacity in this project with as low investement needs as possible.

Sub-aggregators

Typically, the research around finding more flexible capacity focuses in specific fields of industry or large units of electrical devices that can be harnessed to provide demand response. In contrast, the bulk research conducted in this project was around the concept of sub-aggregators who themselves do not own any flexible assets but can enable large masses to enter DR markets. Typically, sub-aggregator already has the monitoring and control capabilities to its resources based on other needs, for instance maintenance or remote management purposes. Thus, the monitoring and control connection to the resource is not built for aggregator purposes only. Sub-aggregators can be for instance EV charging operators, PV system providers, facility management companies, building automation system providers or other system or device providers.

The main characteristics of a sub-aggregator are as follows:

- Sub-aggregator has the ability to monitor and control DERs with small (or zero) investment cost
- Sub-aggregator is a role to be adopted in top of company's primary business, e.g.;
    - Charging Point Operator in the case of smart EV charging
    - Home Automation Service Providers
    - Hardware manufacturers (A/C machine, freezer, water heater etc.)
    - Microgrid System Operators (for energy communities, smart factories etc.)

In this project, we first defined the general characteristics that unify all sub-aggregators. The sub-aggregators that were part of this project clearly show how different the primary businesses can be with the actors that can still act in a unified manner in DR value chain. Indeed, sub-aggregators can be seen as key enablers in harnessing demand response capability in large numbers without major investments needed which is typically the challenge hindering new assets' participation in DR schemes.

Roles and responsibilities

A successful demand response scheme is such that the marketplace needs are fulfilled with little or no inconvenience caused to the flexible resource owners or other end-users. This is possible if the planning and execution take into a consideration the end-users. It is important to understand how the flexible resources are used so that the harnessed flexibility won't cause any harm for the end-user. To make this possible, we have defined roles and responsibilities for the enabling actors in the middle, namely aggregator and sub-aggregator.

Goal is such that all things happen without causing disturbance for the end consumer and so that value sharing is based on total cost estimation with inconvenience factor included.

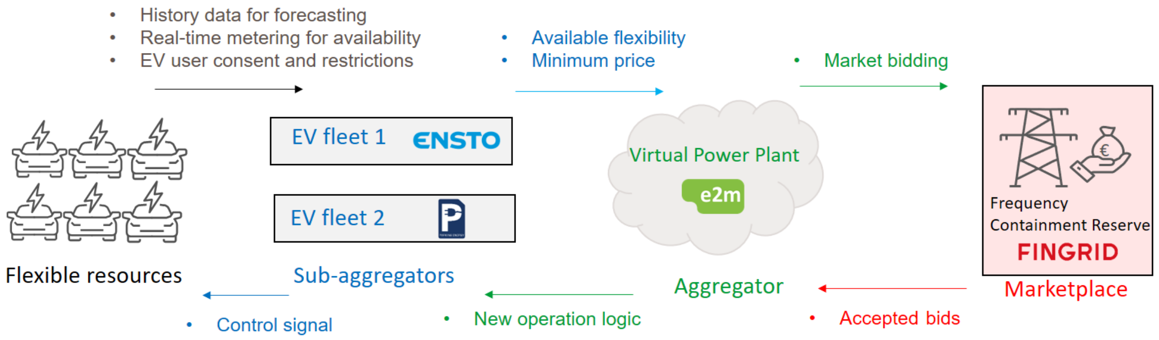


Figure 12. Smart charging scheme on frequency containment market.

Technical Interfaces

Possibly the biggest challenge in harnessing more Demand Response capability for the electricity markets is the vast collection of different technical interfaces that usually require manual work in order to get the ICT connections up and running. The general payback time of investments for Demand Response capabilities has not been estimated to be very good so it is not always worthwhile to use a lot of effort to get the DR capabilities installed.

Technical interfaces are needed in order to get measurement data from the DERs and also for Aggregator and/or Sub-aggregator to be able to control the DERs remotely. There are generally two possible ways to handle the integration.

1. Existing interfaces can be used, but usually some efforts are needed to match the data models and communication protocols from the DER's own interface to Aggregator's back-end system.

2. Installing specifically designed hardware in series with the DER that has remote access for monitoring and controlling the DER in- or output.

In general, the existing setup to start with determines the chosen approach. Both solutions have their advantages and so both approaches are widely used. Using existing interfaces offers scalability if similar units need to be connected to Aggregator's back-end, whereas the installation of specifically designed hardware is usually a bit more reliable and faster to install.

In this project, we had pilots with both approaches. Our partnering Aggregator company, e2m, governs a Virtual Power Plant (VPP) that collects all the information from the DERs. e2m has designed their own solution for both approaches that are briefly opened in more detail below:

Using existing interfaces:

MQTT, installed on premises within existing control or management system, using 3rd party electricians for this, EV smart charging applications etc.

Using e2m Communication Interface:

Usually for over 80 kW units, price, needed technical capabilities on premises, ownership of the box after the installation, VTTs Clivet, Väre/ Savon Voima hydro power unit.

Cyber Security

Global trends such as electrification of everything, digitalisation and prosumer'ism all lead to a situation where electricity end users are increasingly dependent on electricity, they are connected to service providers through various interfaces and also, they are more active participants of the energy sector. Renewable energy generation requires flexible energy consumption and the ones who are capable of that can have economical advantage.

This global trend that drives electricity end users to the center of electricity markets also creates vulnerabilities in terms of cyber security. The more flexibility is needed from electricity end users the more data is collected from them. In order to harness the flexibility of, for example, electric vehicles, the driving routes and charging behaviour of individual EV users might need to be collected. Also, in case of household consumers, harnessing flexibility requires information about the user behaviour in terms of hot water use, space heating and so on. This information can theoretically be used to determine whether user is at home or not which could be valuable information for burglars.

Leaking of critical information is probably the most discussed threat regarding cyber security of Demand Response activities. However, other threats also exist. The remote access to electrical devices can also be used to cause hazards to human life, harm or inconvenience, or economic disadvantage. The topic of cyber security in the smart energy era has been ongoing for several years already but perhaps since the threats have not yet been realized in large scale, the research has not gained focal role. Recently, however, more and more efforts and research funding has been focused to cover this topic, not least because several surveys have revealed the concerns of consumers about this issue. Currently the consumers' concerns are most probably hindering the full potential of end user Demand Response.

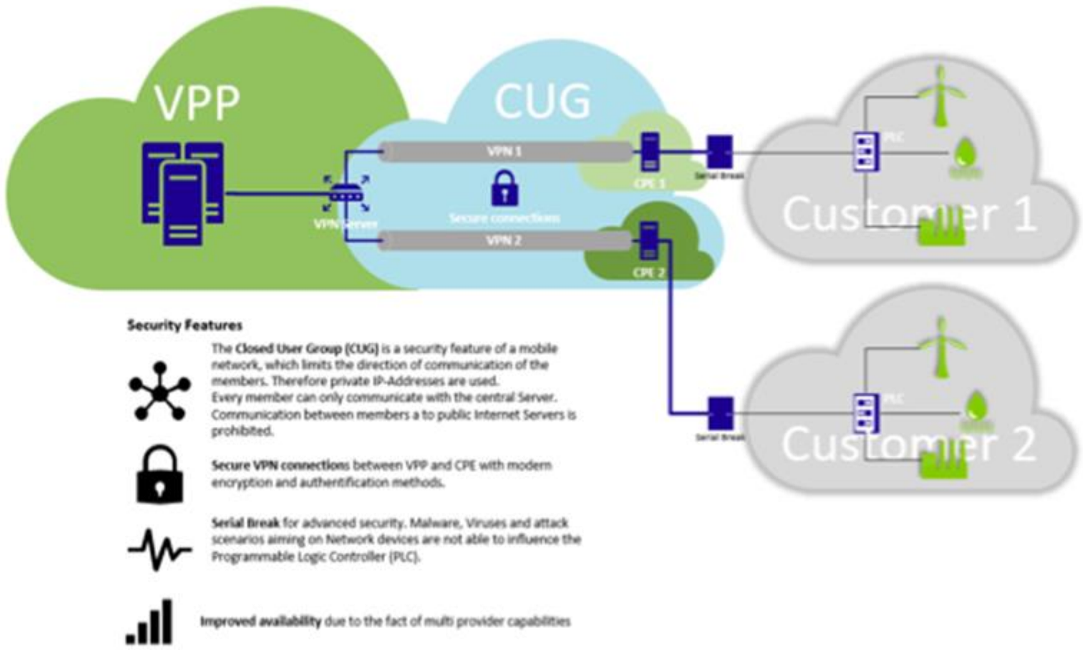


Figure 13. IT Security Concept of a commercial VPP (Source: e2m material)

Mission Innovation - Global Survey

As a part of this project, work within Mission Innovation global network, more specifically Innovation Challenge IC1: Smart Grids was facilitated. As one outcome from this activity, a global survey was conducted in order to clarify the status of demand response worldwide. The survey was conducted through web-based questionnaire that was filled by national experts. Figure 14 presents generic structure of the Mission Innovation collaboration. IC1 was the challenge addressed here.

Figure 14. Overview of Mission Innovation activities.

The work was performed within Innovation Challenge #1 Smart Grids and Task 2: Demand Response under it. The task was specifically to perform a global status review for demand response. The eventual purpose was to define common challenges, identify best practices and find gaps requiring common research and development activities across countries.

The survey was sent to all 20 member countries of IC#1. It included lot of detailed topics, for instance:

- How much DR is currently active
- How much DR potential there is estimated to be untapped
- Where can the untapped potential be found
- Regulation concerning DR participation
- Main barriers for DR (technical / incentives / regulatorial)

The work for summarizing the results is currently running and will be reported soon as a conference presentation. Some implications can already be drawn based on initial results:

- Initial results implicate that the barriers identified empirically in Finland are same also globally (reluctancy to invest in DR capabilities)
- It seems that researchers and regulators see DR as a key part of the future's low carbon power system, but end-users (resource owners) are the ones we need to convince
- At the same, the business potential is still very unsure, especially when looking further in future, thus some reluctancy in take-up is natural
- Business models are needed to incentivize end-users and other DR enablers
- Proof-of-concepts and large-scale piloting are needed to promote benefits and produce early references

The results are partly quantitative, indicating statistics on how different aspects are ranked among countries. Results are also qualitative in many cases, based on open questions, references and further discussions held.

Figure 15 presents a typical statistical output for DR potential across countries. This kind of results will be extended through analysis of open questions.

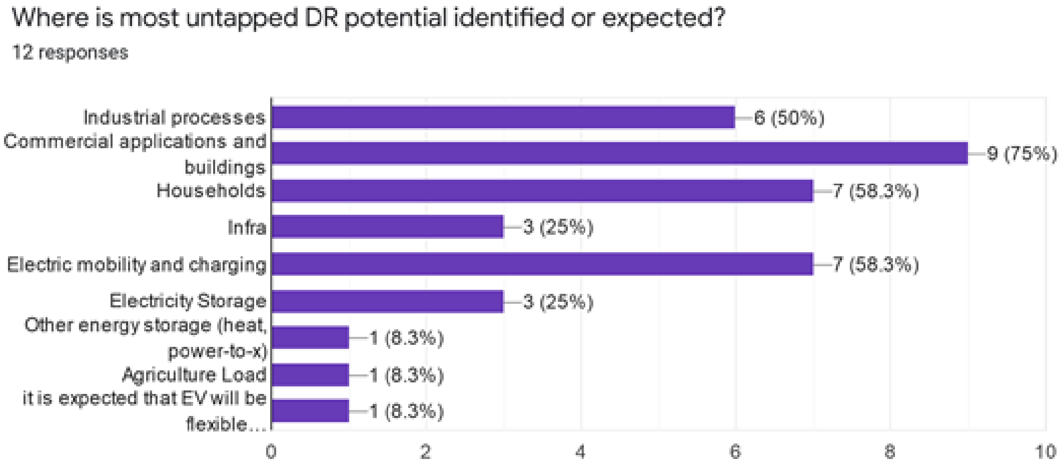


Figure 15. Example of statistical results from the survey: untapped DR potential.

Pilots and Results

The goal in this project was to develop and pilot a real life demand response operation containing all steps in the proposed demand response value chain (see chapter 2). The interest would be focused in the differences and similarities that could be found in the set-up process and operation of different types of sub-aggregators (see Figure 16 below).

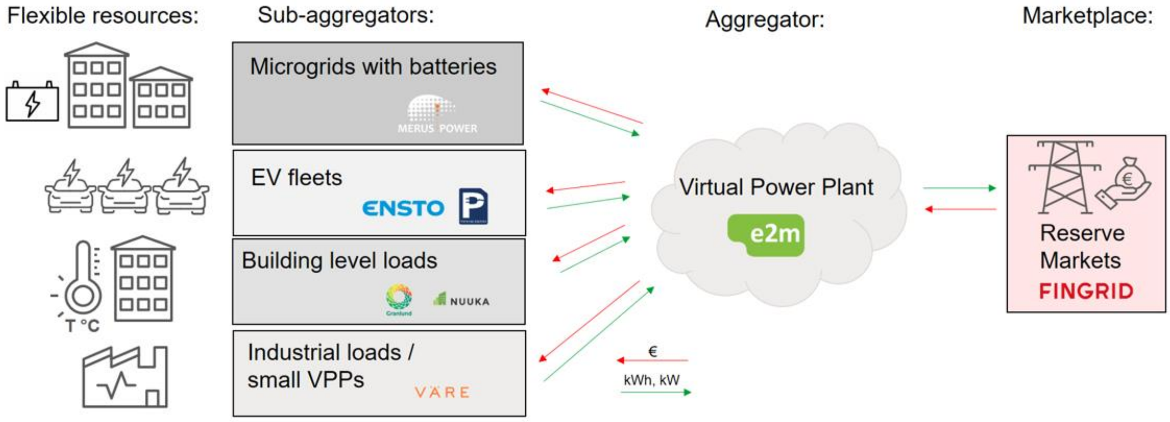


Figure 16. Demand response value chain with different types of Sub-aggregators

During the project a commercial cooperation was formed between e2m and Väre. In the cooperation scheme e2m and Väre joined forces to offer demand response services to Finnish reserve markets. The capabilities of both parties are best exploited in the scheme were e2m's multimarket optimization and bidding expertise is combined with the resources, networks and customers of Väre. Combining flexible resources such as Väre's hydro power plant and new flexibility resources from the field of e-mobility is an example of this innovative new collaboration scheme.

Building level loads (Clivet case)

The integration of the Clivet system into the VPP was a major goal of the aggregation project. The cooling capacity of the unit is 100 kW as seen in Figure 17 (Houttu and Holmstedt 2019[14]). The location is in a VTT office building.

Size – WSAT-XEM			50.4	55.4	60.4	65.4	70.4	80.4	90.4	100.4	110.4	120.4
Cooling capacity (EN14511:2013)	(1)	kW	150	160	172	183	198	225	253	295	319	347
Total power input (EN14511:2013)	(1)	kW	47,9	51,6	55,3	59,1	63,6	72,3	81,6	94,9	102	112
EER (EN 14511:2013)	(1)	-	3,13	3,11	3,12	3,10	3,12	3,11	3,10	3,11	3,12	3,10
ESEER	(1)	-	4,21	4,23	4,20	4,22	4,19	4,22	4,24	4,28	4,26	4,26
Refrigeration circuits		Nr	2	2	2	2	2	2	2	2	2	2
No. of compressors		Nr	4	4	4	4	4	4	4	4	4	4
Type of compressors		-	ON/OFF SCROLL	ON/OFF SCROLL	ON/OFF SCROLL	ON/OFF SCROLL	ON/OFF SCROLL	ON/OFF SCROLL	ON/OFF SCROLL	ON/OFF SCROLL	ON/OFF SCROLL	ON/OFF SCROLL
Standard power supply		V	400/3/50+N	400/3/50+N	400/3/50+N	400/3/50+N	400/3/50+N	400/3/50+N	400/3/50+N	400/3/50+N	400/3/50+N	400/3/50+N

Figure 17. Clivet unit and related data.

[14] Presentation "Building automation and technical service solutions", Smart Otaniemi Aggregator workshop 11.10.2019 in Espoo. Juha-Matti Houttu, Ville Holmstedt, Systempoint Oy.

Since the connection of this technical unit is within a research project, the customer will install an additional communication tool here. This tool enables the customer to read and analyze data. The following Figure 18 (Houttu and Holmstedt 2019) shows the connection principle of the system.

The meter of the unit is a Carlo Gavazzi meter that can read the data with Modbus RTU. The communication tool Fidelix is also connected to the plant using the Modbus RTU protocol. The e2m box is located behind the communication tool. The connection between the two is via the Modbus TCP protocol.

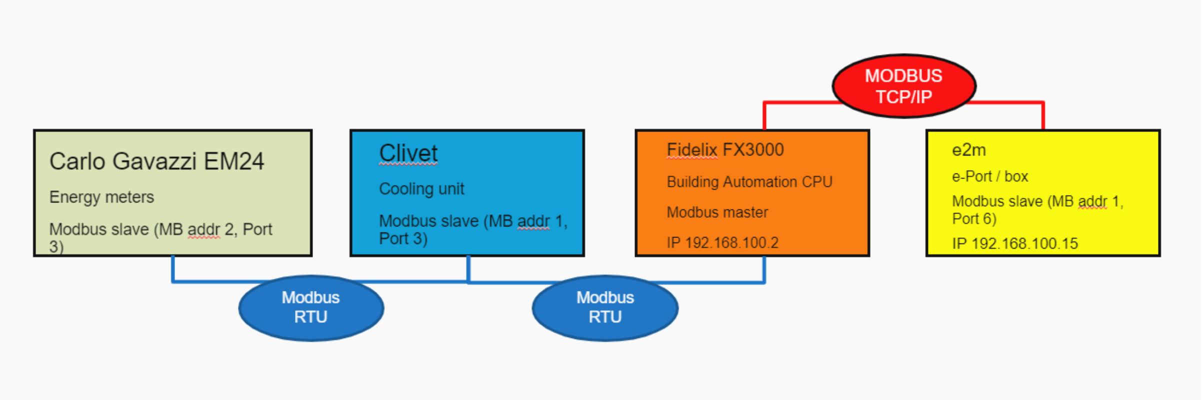


Figure 18. Connection for the Clivet Cooling Unit.

The process of technical integration is divided into 4 steps:

1. Preparation for integration
2. Technical integration
3. Signal Test
4. Prequalification.

During the step 'Preparation for integration', preliminary technical clarifications are made with regard to the system to be connected. The e2m-communication interface is sent off and manuals and guides are made available to the automation engineer.

The step 'technical integration' includes the installation of the box on site and integration of the box into the VPP. Furthermore, the integration of the loads is carried out and the data points are entered into the automation engineer's system.

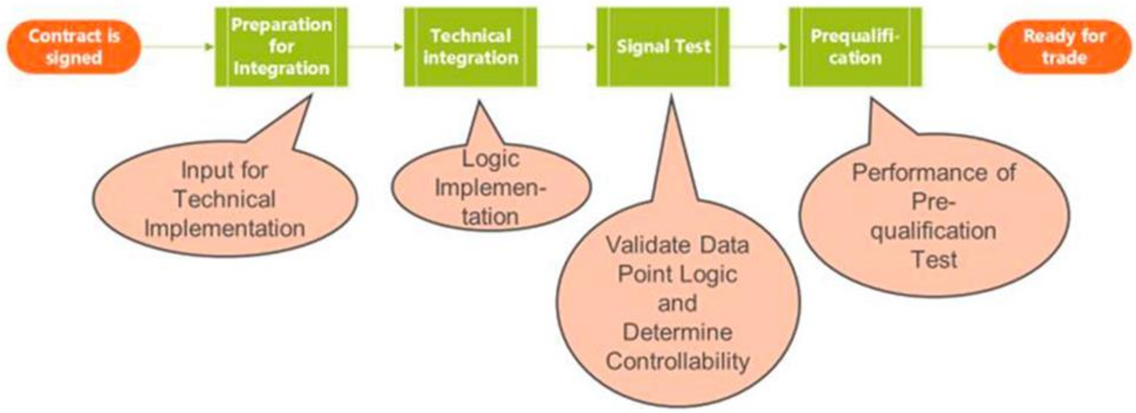


Figure 19. Process of integrating new resources to VPP (Source: e2m material)

Automation engineer Systempoint gave an insight into his tool. In the first picture of Figure 0- 3 (Houttu and Holmstedt 2019), the data points can be seen. In the middle part of the picture the tool with the selected host and the programming is shown. The last part of the figure displays the communication tool Fidelix and the e2m Box. On the box there are LEDs in green, yellow, orange and red.

In the middle part of the box the LEDs are green and yellow, i.e. the signal strength of the antenna is sufficient, and the antennas and SIM card are working and have been installed correctly. In the right part of the box the LEDs are red and orange. This indicates installation errors. Here there was no connection to the VPP. This error has now been corrected and the connection is established.

Corrected were the host (on the part of e2m), but also the data point location in the Modbus TCP Function Code.

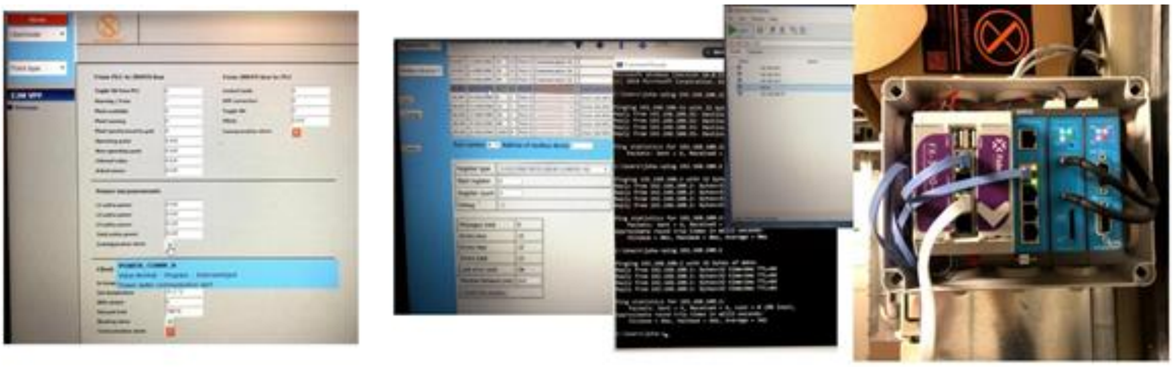


Figure 20. Setup for Clivet Cooling Unit.

The current status of the system is that the signal test has already been performed. All data points are properly installed and validated. Since the system is a cooling system, it operates seasonally in summer.

Another challenge is the four-stage control, which does not allow linear control. This has to be balanced with other systems and then offered in the pool for FCR-N product in the reserve market of Fingrid.

EV fleets (Parking Energy & ENSTO)

Electric mobility will play ever increasing role in the management of power systems. Wider adoption of electric vehicles will cause challenges in local areas where the existing electrical grid is not sufficient to provide peak power loads if the charging is not coordinated. On the other hand with coordination EVs can offer dynamic and powerful aid for many purposes. EVs in households can be used to minimize load peaks which is important in the future if the proposed power tariffs are introduced on top of current DSO tariffs.

When included in Virtual Power Plants, EVs can be used dynamically to serve multiple of services. When considering fleets of EVs, their flexible potential is significant and can be used for example to provide frequency containement services for Fingrid. Charging of individual EVs can sometimes be controlled in small steps which would theoretically be used to provide FCR-n services independently. In reality there are two reasons why it’s not possible. First, the minimum bid size for FCR-n is 100 kW in both directions and secondly most of the charging points / chargers don’t enable step-wise control of the charging.

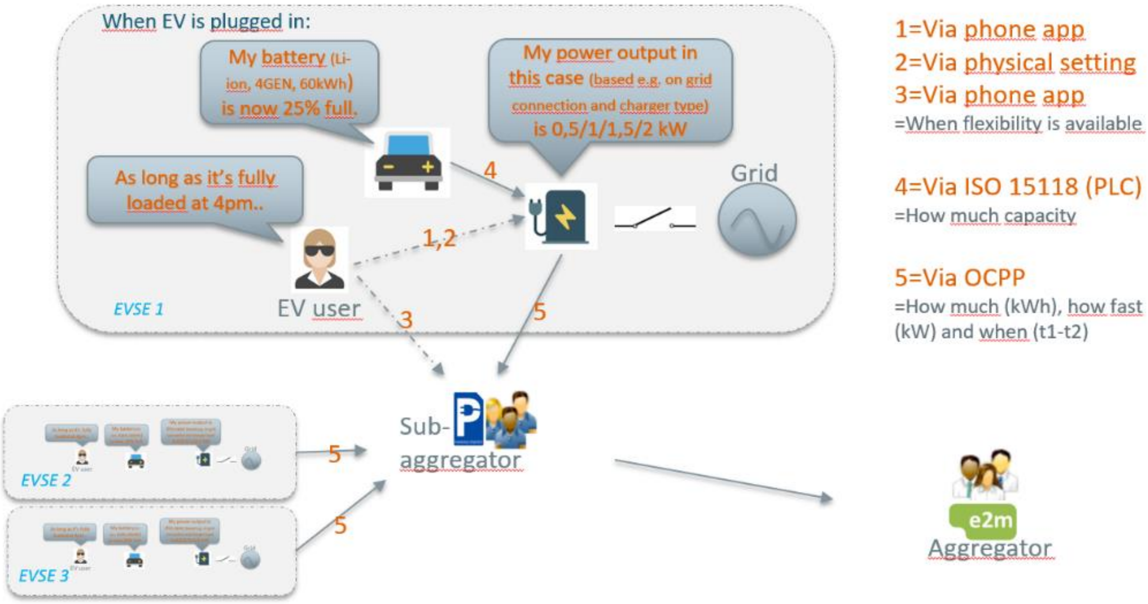


Figure 21. Example of information flow in Smart Charging

Table 4. Sub-aggregator revenue from FCR-n market in 12 simulated schemes

€/year	*10 kW*	*50 kW*	*100 kW*
365h (1h/day)	*62,9*	*314*	*629*
1000h	*172*	*861*	*1 722*
3000h	*517*	*2 583*	*5 166*
8760h (24h/d)	*1 509*	*7 543*	*15 085*

In the table above, possible incomes for Sub-aggregator participating in FCR-n market with different pool sizes and participation rates during one year is presented. In the proposed model, Sub-aggregator would get 70% of the reserve market income and the Aggregator would get 30%. The model assumes that Sub-aggregator has incentivised the load owner to participate in flexible electricity use but since the incentives vary, it was not seen relevant to include load owners in this model as active players. The smart charging can happen at night time or when the EV is otherwise idle for a long time and so the EV user would not even notice that flexibility was activated. Hourly price (averaged) for the last 8 years (2011-2018) was 24,60€/MWh. It should be noted, however, that the price volatility is great.

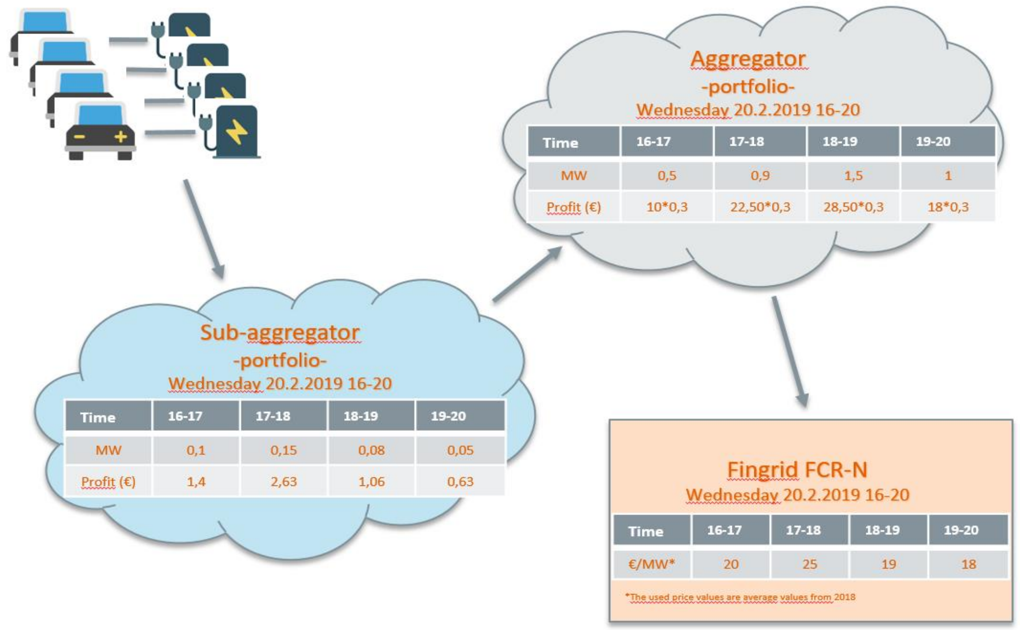


Figure 22. Agregator - Sub-aggregator value sharing model/method

Dissemination

One of the key ideas in Smart Otaniemi Innovation Ecosystem is the co-operation between research, industry and regulative parties. This was well executed in the Aggregator pilot were multiple meetings were held between VTT, industrial partners and Fingrid, the latter representing the regulative party since the business case in the Aggregator pilot was formed on top of Fingrid's reserve markets.

Aggregator Webinar

Most visible dissemination of the project results was a webinar that was broadcasted live for interested listeners. The idea was to present the concept of Sub-aggregator as a key enabler of harnessing DR. In the concept the Sub-aggregator acts as an enabler between the flexible resource owner and the commercial Aggregator. The recording can still be viewed from the Smart Otaniemi website.

The event was held in 5th of September in 2019 so that the participating experts were at one place and all the listeners were connected to the event via Internet. Participating in this event as experts were three people, Matti Aro from VTT, Olli Parkkonen from Nuuka Solutions and Pia Ruokolainen from Fingrid. The event was hosted by Antti Ruuska from VTT.

The webinar received positive feedback and inquiries for more information. At the webinar event, also questions from the audience were received. Statistics tell that the webinar was viewed not only in Finland but also international interest was recorded.

Technical Workshops

Project partners e2m, Väre and VTT organised as a joint effort two technical workshops targeting Project Partners as well as selected automation companies in October 2019. e2m's German Experts joined the workshop. The first workshop was organised at Väre Head Quarters in Kuopio and the second at VTT premises in Otaniemi, Espoo. Automation houses' invitations and selection was motivated by these companies' capability to install e2m-Port for potential customers technical devices in the future. Companies like Insta, Scheider, Slatek, Fidelix, Systempoint, Adconsys etc. took active part in workshops of five to six hour each. There were altogether 20 plus 30 participants per day.

The topics ranged from company presentations and VTT's motivational overview on Virtual Power Plant's role in the Future energy system down to practical e2m Finnish installation use cases and detailed process descriptions with practical hints on technical units onboarding to e2m Virtual Power Plant and later to Fingrid's FCR-N market. All in all the subject VPP integration subject was made tangible and practical as well as the issue demystified for Automation engineers.

Figure 23. Pictures from workshop at VTT.

European Energy Markets -19

One of the project outcomes was a piloted concept for Charging Point Operators (CPO) to act as intermediate between Aggregator and EV user. The role in more specific is called a Sub-aggregator and it includes monitoring and controlling the charging events. The concept was designed with the actual players, e2m as an Aggregator and Ensto as well as Parking Energy as Sub-aggregators. In this model, the CPOs monitor and forecast the charging behaviour of EV users and activates flexibility by scheduling the charging events.

The concept was formatted into a publication together with VTT, Tampere University and e2m. The publication was accepted to be presented and published in European Energy Markets Conference in autumn 2019 in Ljubljana, Slovenia. The main author, Matti Aro, presented the concept paper in the actual event and some valuable comments were received. The idea is to further develop the concept of Sub-aggregator and to test it also with other flexible assets than EVs.

Copenhagen Seminar on Flexibility

In June 2019 the proposed business model containing sub-aggregator as a key enabler in harnessing more flexible potential was presented in Copenhagen, Denmark. The seminar in which the authors participated was called “Flexibility is the cornerstone of the future energy system”. It was hosted by the Danish Intelligent Energy Alliance which is an initiative by the Danish Energy Association.

In the seminar, the concept of sub-aggregation was presented and comments were asked. The audience there first felt that adding yet another shareholder to the value chain would weaken the business case for the others. However, by adding the sub-aggregator in the scheme will enable significant amount of flexibility to enter the markets and most of all, with little or no cost at all. This gave the audience a new angle to look at this and the authors feel the conversation helped both sides to broaden the perspective in this whole flexibility matter.

The value that our working group had from this seminar came in the form critical questioning of the concept. At the end of the seminar the audience in the seminar was left with an optimistic view about the concept presented, they felt that with this concept it would indeed be possible to get quickly and with low investment cost significant amount of flexibility to the markets.

Mission Innovation workshop at European Utility Week

Mission Innovation working group for IC#1 Smart Grids had a workshop during European Utility Week in Paris on November 2019. In this workshop, the Smart Otaniemi Aggregator Business Pilot was presented, with sub-aggregator concept discussed with more details. Also early results for the demand response survey described earlier were presented.

Exploitation of Results

As a direct outcome from this pilot, Smart Otaniemi is involved in new EU H2020-project SENDER, which is starting in October 2020. VTT is the official partner in the consortium. The sub-aggregator concept will be used as one option during the project. A practical pilot on aggregating EV charging in Otaniemi will be used as the Finnish pilot case.

Concept piloting has also advanced in Porvoo with ENSTO and e2m. This pilot has been built together with Finnish-German project EVALIA focusing on smart charging. The continuation of the pilot will take place within EVALIA.

e2m have received good feedback from potential sub-aggregators. The learnings made in the project can be used in commercial context soon. E2m's VPP partner - Väre in Finland it's personnel and their potential customers start to learn the possible service model and potential for added revenues.

Additionally, the discussions with several Sub-Aggregators have proceeded in positive mood in Spring 2020. One of the main benefits is that sub-aggregation related concept by VTT has taken shape - as a matter of fact the sub-aggregator concept and thematic were hardly used in Finland before the project. VTT has put the frame around and added content to the conceptual idea

Summary

This work has conducted a systematic study on aggregation of small resources into markets in a cost-efficient manner. Concept of sub-aggregator has been introduced for the purpose. Work on business models enabling sub-aggregation has been conducted. Also practical work for specifying and implementing interfaces between actors has taken place. Feasibility of piloting the new solution was assessed for several sites within Otaniemi and beyond. Evantually practical pilot installations took place at two sites, at VTT office building and VTT research laboratory.

Necessary technical infrastructure building blocks of Virtual Power Plant for the Finnish Market were all covered comply with Finnish regulation. Such project belonging areas were:

- VPP’s technical connection to Fingrid market
- Pre-qualification procedure
- Safety concept for technical connection
- Development of Trading concept and its implementation
- Technical connection process and onboarding of the devices.

One of the underestimated areas in project planning was need for training and support materials as well as the area of knowledge sharing. The VPP understanding was way behind the for instance from international markets. Practical workshops were arranged to provide support for installations.

As a common conclusion, the sub-aggregator concept work has gained lot of interest within different groups. The interface development work between partners has been very creative and concrete. Business models and market aspects have been thoroughly studied mostly by VTT. Most challenges have been faced within practical piloting. For instance within buildings there are several actors that need to be involved and motivated.

New projects are building on the basis created, including for instance new H2020 project SENDER started in October 2020.